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Mathematical Study of CO_2 Dispersion in Carbonated Water Injection Enhanced Oil Recovery Using Non-Equilibrium 2D Simulator

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Abstract : CO_2 based enhanced oil recovery (EOR) techniques have gained massive attention from major oil firms since they resolve the industry's two main concerns of CO_2 contribution to the greenhouse effect and the declined oil production. Carbonated water injection (CWI) is a promising EOR technique that promotes safe and economic CO_2 storage; moreover, it mitigates the pitfalls of CO_2 injection, which include low sweep efficiency, early CO_2 breakthrough, and the risk of CO_2 leakage in fractured formations. One of the main challenges that hinder the wide adoption of this EOR technique is the complexity of accurate modeling of the kinetics of CO_2 mass transfer. The mechanisms of CO_2 mass transfer during CWI include the slow and gradual cross-phase CO_2 diffusion from carbonated water (CW) to the oil phase and the CO_2 dispersion (within phase diffusion and mechanical mixing), which affects the oil physical properties and the spatial spreading of CO_2 inside the reservoir. A 2D non-equilibrium compositional simulator has been developed using a fully implicit finite difference approximation. The material balance term (k) was added to the governing equation to account for the slow cross-phase diffusion of CO_2 from CW to the oil within the gird cell. Also, longitudinal and transverse dispersion coefficients have been added to account for CO_2 spatial distribution inside the oil phase. The CO_2-oil diffusion coefficient was calculated using the Sigmund correlation, while a scale-dependent dispersivity was used to calculate CO_2 mechanical mixing. It was found that the CO_2-oil diffusion mechanism has a minor impact on oil recovery, but it tends to increase the amount of CO_2 stored inside the formation and slightly alters the residual oil properties. On the other hand, the mechanical mixing mechanism has a huge impact on CO_2 spatial spreading (accurate prediction of CO_2 production) and the noticeable change in oil physical properties tends to increase the recovery factor. A sensitivity analysis has been done to investigate the effect of formation heterogeneity (porosity, permeability) and injection rate, it was found that the formation heterogeneity tends to increase CO_2 dispersion coefficients, and a low injection rate should be implemented during CWI.

Keywords : CO_2 mass transfer, carbonated water injection, CO_2 dispersion, CO_2 diffusion, cross phase CO_2 diffusion, within phase CO2 diffusion, CO_2 mechanical mixing, non-equilibrium simulation
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